Standard for Infiltration Structures

Definition

Two general types of structures may be used for infiltration of runoff. An *infiltration basin* is a water impoundment facility constructed over highly permeable soils. The appearance and construction of an infiltration basin is similar to that of a dry or wet pond. An impoundment is created by excavating the ground or constructing an embankment. Like the dry or wet pond, the infiltration basin can also be designed as a multi-stage, multifunction facility to achieve diverse stormwater management objectives. An *infiltration trench* is used to temporarily store and discharge stormwater runoff from small drainage areas where a large open basin would be impractical. The trench is typically filled with stone and left open or covered with topsoil and vegetated. A *dry well* resembles an infiltration trench in design, but is mainly for the collection of rooftop runoff, and has a separate Standard.

Conditions Where Practice Applies

The use of infiltration structures for water quality control is practical in small drainage areas where soil is sufficiently permeable to allow a reasonable rate of infiltration. They should be designed to infiltrate the runoff produced by the water quality storm (1.25” in 2 hours). Runoff greater than the water quality volume should be either passed through or detained through means of a conventional basin. The seasonal high water table must be at a depth of at least three feet. Infiltration devices are not applicable in areas producing high concentrations of suspended particles.

Runoff from industrial or other high pollutant - load areas is not compatible with these facilities. Infiltration facilities should not be used in the following situations:

1. In most industrial areas and commercial developments where petroleum products, herbicides, pesticides or solvents may be loaded/unloaded, stored or applied within drainage areas, and especially in locations with soluble heavy metals and toxic organics.

2. Where hazardous materials are expected to be present in greater than ‘reportable quantities’ as defined by U.S. Environmental Protection Agency (USEPA) in the Code of Federal Regulations (40 CFR 302.4) or,

3. For sites with high risk of spills of toxic materials such as gas stations and vehicle maintenance facilities.

4. Soil beneath the structure does not have the necessary unsaturated void space (volume) to store the entire volume of the design storm.

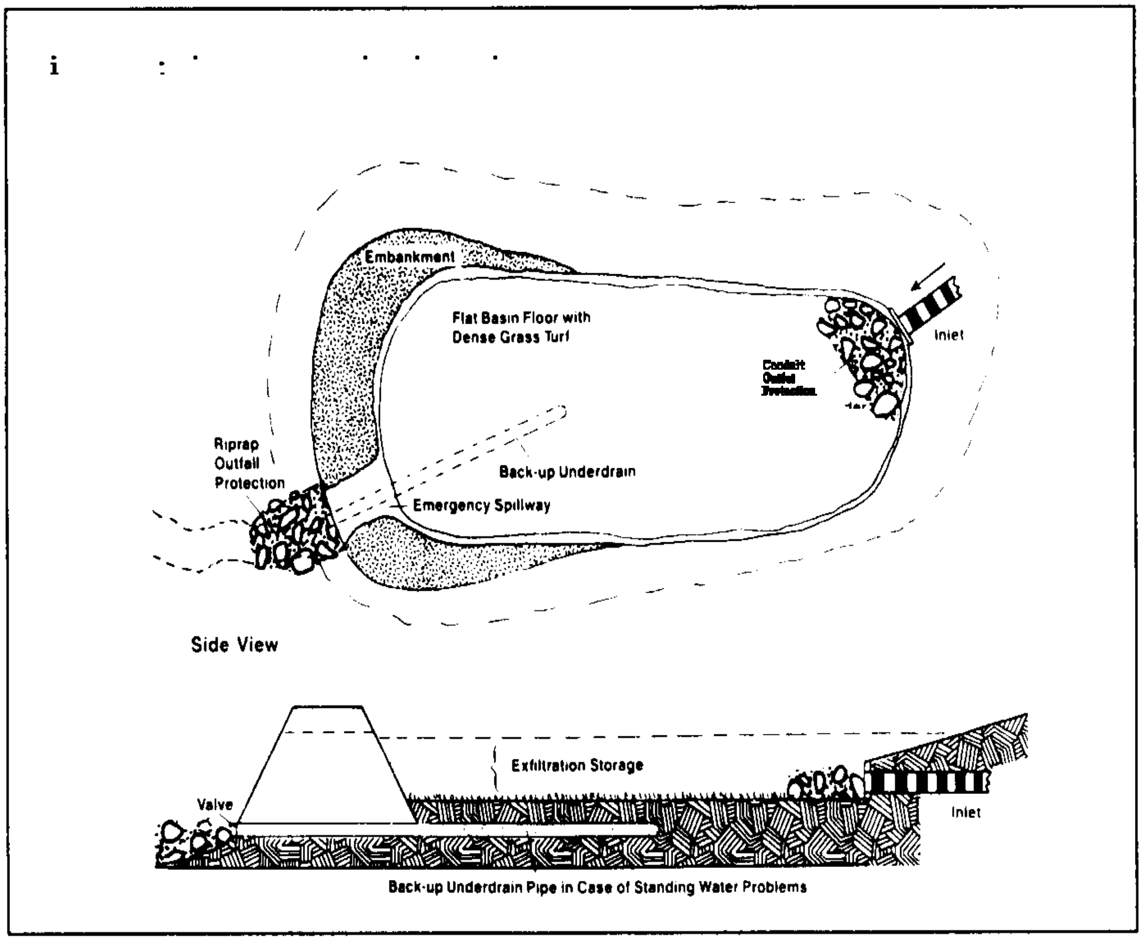


Figure 1. Typical Infiltration Basin

<u>Design Criteria</u>

The minimum design storm shall be the NJDEP Water Quality Storm (1.25" in 2 hours).

The volume of runoff shall be determined by the USDA NRCS TR-55, TR-20 or HEC-1. The volume of the runoff shall be calculated from impervious surfaces only. All impervious surfaces shall be assumed to be connected. Trenches are used for small drainage areas including residential lots, commercial areas, small parking lots and open space areas. Total drainage area shall be a maximum of 1 acre per structure (for basins).

Topography of the location is an important consideration for basin operation. Ideally, basin construction should not occur where surrounding slopes are greater than 10%.

1. Sensitivity of the Area

The planning of an infiltration structure site should consider the geologic and ecological sensitivity of the proposed site. Sensitive areas include: FW1 streams, areas near drinking water supply wells and areas of high aquifer recharge. Infiltration structures should be sited at least 100 feet from a drinking water supply well. They should also be sited away from foundations to avoid seepage problems. Measures should be taken in areas of aquifer recharge to insure good quality infiltration to protect ground water supply. Infiltration structures should be located away from septic systems to protect the systems from failure.

2. Surface Area and Depth

Basins. Large, shallow basins in contrast to small, deep basins increase exfiltration particularly where soil infiltration capacity is marginal. Drains located at the bottom of the basin on a 1-2 percent slope can be utilized to enhance basin draining. Wire mesh stone-filled baskets are recommended rather than loose stone to provide a smooth top surface to facilitate mowing of the basin bottom and prevent unauthorized removal. The bottom of the drain should be located at least three feet from the seasonal high water table.

Trenches. By designing the trench wider than it is deep, pollutant removal can be enhanced. Increased surface area creates a larger area for soil filtering. Broader trench bottoms reduce the risk of clogging at the soil/filter interface by spreading out exfiltration.

3. Buffers

A minimum buffer of 25 feet from the edge of the basin floor to the nearest adjacent lot is recommended. Grass swales or vegetative buffers around the basin or trench are recommended to protect against erosion and to capture particulate matter and nutrients in the runoff prior to entry.

4. Bottom of Infiltration Basins

The establishment of a dense turf of water tolerant grass on the floor and the side-slopes of this basin is essential for improved performance of a basin. Refer to the appendix for selecting appropriate turf grasses.

An alternative 12 inch non vegetative layer, such as coarse sand, may be considered instead of a vegetative bottom. This layer should promote infiltration and facilitate desilting. The non vegetative material can be cleaned of sediment or replaced as needed. Before using this alternative, factors such as weed growth, aesthetics and movement of maintenance personnel and equipment should be considered. Grass strips bordering nonvegetative linings should be designed to permit mowing along edges.

5. Slopes (Basins only)

The grading of the basin floor should be as level as possible (with the slope approaching zero) to achieve uniform spreading across the breadth and the length of the basin. Side slopes should be no steeper than that which will safely accommodate maintenance equipment.

6. Maximum Draining Time

The maximum depth of exfiltration storage should be adjusted so that stormwater completely drains into the soil within 72 hours for the design storm event. Complete exfiltration within this time frame is essential to maintain the aerobic environment in the soil profile long enough to promote bacteria that aids in the removal of pollutants and also to ensure that the structure will be empty and ready in time for the next storm event. For design purposes, use a safety factor of two for infiltration rate value by field testing.

7. Minimum Draining Time

The design of the infiltration structure should also allow some minimum draining time to ensure meaningful reduction in runoff pollutants. Moderate to poor pollutant removal has been observed in partial infiltration systems that detain water for less than six hours. Short residence times do not allow for adequate infiltration, which in turn limits pollutant removal capability.

8. Principal Spillway, Emergency Spillway, Dam, Embankment and Inlet and Outlet Structures (Basins only)

Refer to Standards for Soil Erosion and Sediment Control in New Jersey, Appendices for structural guidelines for stormwater management basins or local state, county or municipal requirements.

9. Rate of Infiltration

The site must have a good infiltration rate to be suitable for recharge. The rate of infiltration may decrease over time due to the accumulation of sediments (especially in the floor of a basin) before routine maintenance is performed. Also the infiltration rate in actual working conditions may be different than observed during percolation tests. Therefore, a factor of safety of two shall be used from observed hydraulic conductivity.

10. Design Procedures for Stormwater-to-Soil Infiltration

The design of infiltration structures is based on Darcy' s Law, which is : **Q = kiA**
where:
Q is the rate of infiltration (cfs)
k is the hydraulic conductivity of the soil (f/s)
I is the hydraulic gradient
A is the area of percolation (sq. ft.)

Average Hydraulic Gradient = D_{avg} /d
Minimum Hydraulic Gradient = D_1/d
Maximum Hydraulic Gradient = D_2/d

The hydraulic conductivity is either field measured or laboratory measured for the soil on site. A number of percolation tests should be done to obtain a reliable measurement of permeability of the underlying soil. A safety factor of two shall be used for any difference in hydraulic conductivity from field test and actual working conditions.

Typical ranges for hydraulic conductivity (feet/sec) are:

High Flow Rate .... Low Flow Rate

Clean Gravel		Mixture of clean sand and gravel to clean sand		Very fine sand, silts		Mixtures of sand and silt		Clays	
3.3×10^{-2}	3.3×10^{-4}	3.3×10^{-3}	3.3×10^{-5}	3.3×10^{-5}	3.3×10^{-7}	3.3×10^{-6}	3.3×10^{-8}	3.3×10^{-8}	3.3×10^{-11}

11. Construction Specifications

A back-up drainage system must be provided in case infiltration capacity fails or is exhausted.

The area planned for the structure should be roped off to prevent heavy equipment from compacting the underlying soils before the development site is graded.

When using a basin, excavation should be limited to within two feet of the final design elevation of the basin floor if it is to be used as a temporary sediment basin during the construction phase. The sediment that accumulates during the construction phase can then be removed before the basin undergoes final excavation at the completion of the development. If the basin is not intended for sediment control, diversion berms should be placed around its perimeter during all phases of construction to divert all sediment and runoff completely away from the basin. Actual construction of the basin should begin only after the site has been completely stabilized.

To prevent compaction of the subsoil which will reduce its infiltration capacity, basins should be excavated with light earth moving equipment, preferably with tracks or over-sized tires rather than the normal rubber tires. Once the final construction phase is reached, the floor of the basin shall be deeply tilled with a rotary tiller or disc harrow and smoothed over with a leveling drag or equivalent grading equipment.

Within a week of construction, the floor and the side slopes of the basin should be seeded with water tolerant, low maintenance and rapid germinating grasses such as fescues. The condition of the newly established vegetation should be checked several times over the first few months, and, if necessary, remedial actions such as re-seeding, fertilizing and irrigation should be undertaken.

12. Design

A. Infiltration Basin

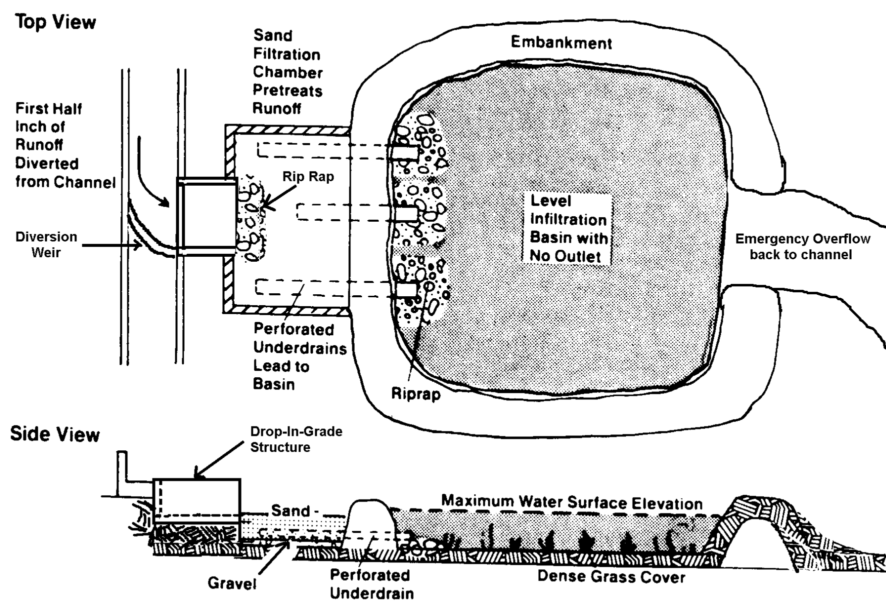
This design is used at sites with extremely permeable soils. The basin is sized to accommodate and infiltrate the entire runoff volume from a one-year or smaller design storm. The only outlet from the basin is the emergency spillway which discharges the larger storms. The use of this design variation is therefore limited to smaller (5 to 20 acre) watersheds. (Figure 1.)

B. Combined Infiltration / Detention Basin

This design variation provides detention zones above the infiltration zone for the control of the larger storm events. The one-year storm outlet orifice is placed at the water quality storm elevation, creating a zone of dead storage below it. The runoff volume, confined within this dead storage zone, is completely exfiltrated.

Runoff volume in excess of the dead storage is discharged through the low flow orifice while very large runoff volumes, associated with larger design storms are discharged through the riser.

The infiltration basin designed for water quality (infiltrating the water quality storm runoff) may also be designed as a detention basin for lower frequency storms such as the 2, 10 and 100 year events. The lowest level orifice outlet should be located at or above the peak water elevation for the water quality design storm in the basin.



Source: MWCOG, 1987

Figure 2. Typical Off-line Infiltration Basin

C. Off-line Infiltration Basin

Off-line design is used to divert and infiltrate the first flush runoff volume from a storm sewer or a surface channel. They are particularly useful in situations where infiltration cannot be achieved by a downstream infiltration facility due to soil limitations. As an example, an off-line design modified from Austin DPW (1986) is shown in Figure 2. This design utilizes a combination of an off-line sand filter and an infiltration basin to treat the first flush runoff volume. A weir is placed across a natural or man-made channel that diverts runoff into an off-line sand filter. After percolating through the sand filter, the runoff is collected by underdrains which lead to a level, vegetated, infiltration basin. This is a particularly useful design for drainage areas which produce high sediment and hydrocarbon loads. Note: the practice of diverting the ‘first flush’ storm may also be employed in a similar fashion with an infiltration trench design.

D. Infiltration Trench

An infiltration trench is defined as a subsurface trench that is used to temporarily store runoff in a stone filled reservoir and exfiltrate the runoff through the surrounding soil media (Figure 3). A minimum 20 foot vegetated buffer strip is required around the perimeter of the trench to prevent the entrance of sediments. The surface of the trench will consist of either a stone covered area or a grass covered area with an inlet. If the trench surface area consists entirely of stone, wire mesh mattresses or large size stone shall be placed on the surface to prevent vandalism. A grassed trench surface will require an inlet so runoff can effectively enter the stone filled reservoir storage area. The inlet shall be designed to remove heavier sediments to prevent the clogging of the stone void spaces. A filter fabric material will be required at the interface of the soil and reservoir area or below the wire mesh mattress and around the sides and bottom of the trench.

Where the effectiveness of source controls is limited, it is recommended that infiltration systems include a detention basin or pretreatment to settle out or remove pollutants such as metals, hydrocarbons and other particulate matter, prior to infiltration. Infiltration trenches are not intended to remove coarse sediments. These must be removed by pre-treatment and control of sediment input, prior to their entry into the trench to prevent clogging of the stone reservoir. A combination of source controls, detention and infiltration will protect water quality while filtering out a portion of those substances which contribute to system failure.

By designing the trench wider than it is deep, pollutant removal can be enhanced. Increased surface area creates a larger area for soil filtering. Broader trench bottoms reduce the risk of clogging at the soil/filter interface by spreading out exfiltration. In addition, an observation well should be installed at every trench. The well is used to monitor the performance of the trench and helps to mark the trench location (Figure 3).

After the trench has been excavated, the bottom and the sides of the trench should be lined with filter fabric to avoid the migration of the soil particles into the stone voids. The fabric should be placed flush with the bottom and sides with a generous overlap at the seams. Care should be exercised in the selection of the proper kind of filter fabric, since available brands differ significantly in their permeability and strength. Prior to installation of the filter fabric, the bottom and side walls of the trench should be inspected for the removal of any protruding material such as tree roots that may rupture the filter fabric.

Considerations

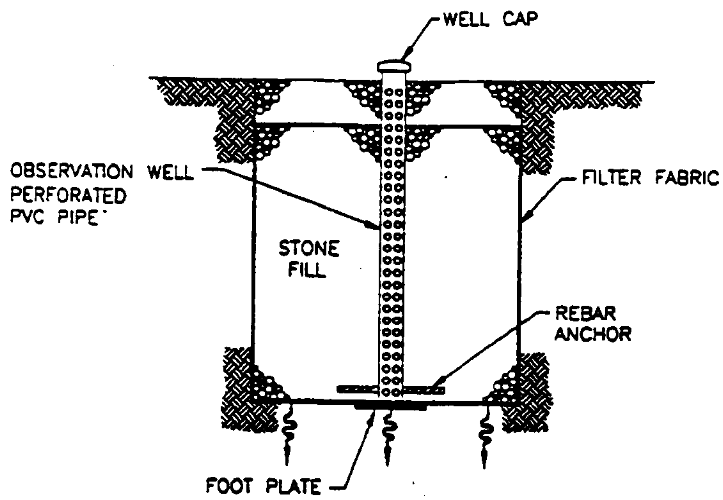
Diagrams of the basic design of infiltration practices is shown in Figures 1 -3. Infiltration structures present some practical design problems. When planning for a hydraulically functional infiltration structure which provides water quality benefits, consideration should be made for soil characteristics, depth to the water table, sensitivity of the region and runoff water quality. Particular care must be taken when constructing infiltration structures in areas known to be underlain by solution prone rocks. See the Appendix, Standards for Soil Erosion and Sediment Control in New Jersey, for further guidance in areas with Karst Topography.

1. Soil Characteristics

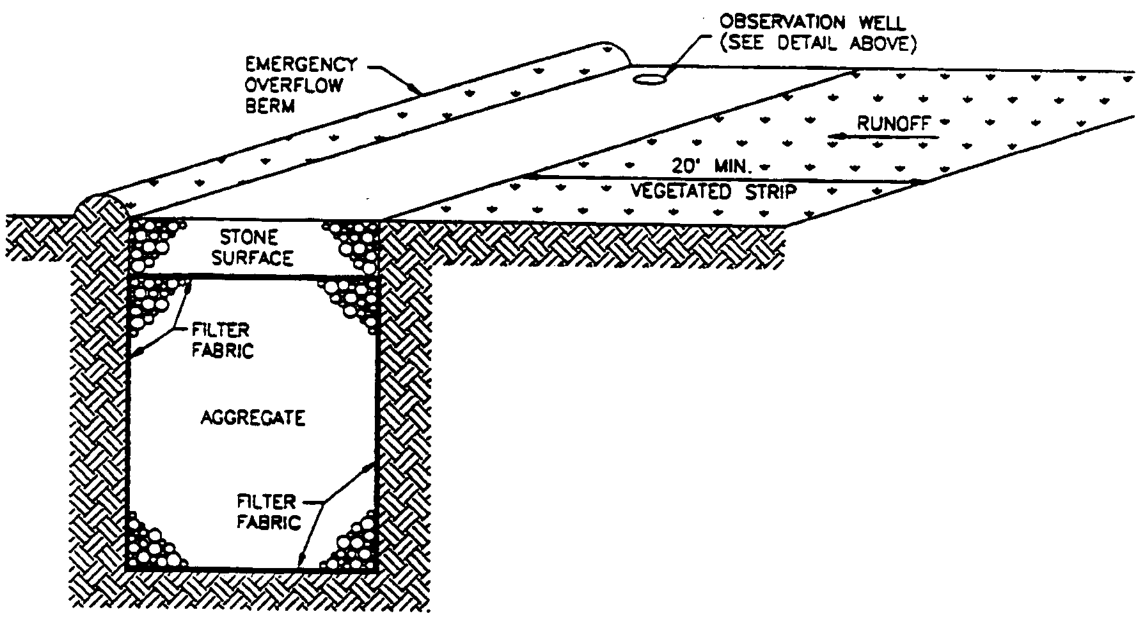
Soils are an important consideration for site suitability. The first step in determining site suitability would be to consult the appropriate soil survey available through the local soil conservation district. Information on soils is also generally collected during a geotechnical site investigation for large land developments to determine foundation conditions for structures. The excavation of an eight to 10 foot deep test pit or trench is a preferred method for mapping the stratigraphic profile and collecting samples. For greater depths and where considerable stratification is anticipated, boring with a continuous splitspoon sampler is an appropriate sampling and exploration practice. The recommended minimum depth for subsurface exploration is 5 feet below the anticipated design depth or to the static ground water table.

DRAFT

The permeability or infiltration rate of the soil will be a limiting factor in the use of an infiltration device. Soil permeability must be great enough to drain the water quality design storm within 72 hours. The soil infiltration rate should be .50 inches/hour or greater. Suitable soils include sand, sandy loam and loamy sand. These soils have the



OBSERVATION WELL DETAIL



INFILTRATION TRENCH DETAIL

(Source: Smith, Demer, and Normann)

Figure 3. Infiltration Trench

capacity to attenuate pollutants because of their silt and organic matter content to which substances such as metals can bind. The removal capacity of the soil should not be relied upon to replace source controls. Soil may provide an effective medium to filter or remove residual pollutants, but may not remove high to moderate pollutant loadings. Certain pollutants, such as metals, bacteria, nitrogen and phosphorus, are removed when the stormwater percolates through the soil beneath the basin floor. Removal mechanisms are quite complex and may involve sorption, deposition, trapping/straining and biological degradation or transformation. Basins and trenches should not be constructed over fill soils unless those soils are specifically designed for enhanced infiltration.

2. Depth to Ground Water or Bedrock

The location of the seasonal high water table can be determined by field observations of static water level in borings, changes in soil moisture content and changes in soil color. Ground water levels fluctuate seasonally and annually. Field observations should be supplemented with historical research on local ground water conditions.

The minimum depth to the seasonal ground water table or bedrock must be at least three feet from the bottom of the structure. This depth is based upon promoting complete infiltration, preventing standing water or soggy surfaces, hydraulic considerations to protect against mounding and subsequent flooding of the structure. Soils overlying a seasonal high water table deeper than three feet and with a high capacity for attenuation of pollutants are the most desirable for infiltration.

3. Runoff Water Quality

The quality of runoff water entering an infiltration device is a primary consideration in determining the design of an infiltration system or whether infiltration is even feasible. Pollutant loadings and pollutant types will vary based upon topographical features of the region and land use: commercial, agricultural, residential or industrial.

Sediment is a nonpoint source pollutant which affects infiltration and its accumulation is a primary cause for infiltration basin failure. Infiltration devices are susceptible to clogging and subsequent failure if significant sediment loads are allowed to enter the structure. Sediment also transports pollutants which are bound to its structure. These structures should not be installed until all land within the construction area is stabilized. During basin construction, precautions should be taken to prevent soil compaction and sediment contamination.

Soils have a limited capacity for the treatment of bacteria, nitrogen and phosphorus. A majority of pollutants are either attenuated in the soil column or, like road salts and some pesticides, go directly to the water table. The planning of an infiltration structure must consider the pollutants which will be generated and whether these pollutants will degrade water quality. Measures such as settling or pretreatment in coordination with other controls can decrease the pollutant loading to the structure and decrease its susceptibility to failure.

Operations and Maintenance

Infiltration structures should be inspected on a routine basis (at least semiannually) and after a major storm event. Important items to examine include: differential settlement, cracking, erosion, leakage or tree growth on the embankment (basins), the condition of the riprap in the inlet and pilot channels (basins), sediment accumulation and the density of grass. Site design should be reevaluated should clogging occur to determine the factors responsible for the problem.

These inspections should be used to determine the effectiveness of the regular maintenance schedule as well as to determine the timing of corrective maintenance procedures.

Buffers, side slopes and basin floors should be mowed at least twice a year. A routine should be developed for the removal of trash and debris. Grading and landscaping around facility inlets should be designed to facilitate mowing, trimming, debris removal and other general maintenance. Grass clippings and accumulated organic matter must be removed to prevent the formation of an impervious organic layer or mat. Trees, shrubs and other vegetative cover also require periodic maintenance such as fertilizing, pruning and pest control to maintain healthy growth.

For basins, annual tilling operations maintain infiltration capacity. These tilled areas should be revegetated immediately to prevent erosion. Deep tilling can be used to break up clogged surface layers followed by regrading and leveling. Sand or organic matter can be tilled into the basin floor to promote a restored infiltration capacity. Sediment removal procedures should not be undertaken until the basin is thoroughly dry. The top layer should be removed by light equipment to prevent compaction. The remaining soil can be retilled and disturbed vegetation replanted.

Trenches may require partial or complete removal of the topsoil/vegetation covering (if used), or the removal of the stone fill material should infiltration capacity become severely reduced. Pretreatment areas, buffers, inlets etc. also will require periodic maintenance to protect the infiltration capacity of the trench.